Miscellaneous Paper EL-94-9
September 1994

US Army Corps
of Engineers
Waterways Experiment
Station

# Proceedings of the International Symposium on Hawaiian Stream Ecology, Preservation, and Management

*by Carl M. Way, Editor*









Prepared for U.S. Army Engineer District, Honolulu
and State of Hawaii, Commission on Water Resources Management

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U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199



Final report

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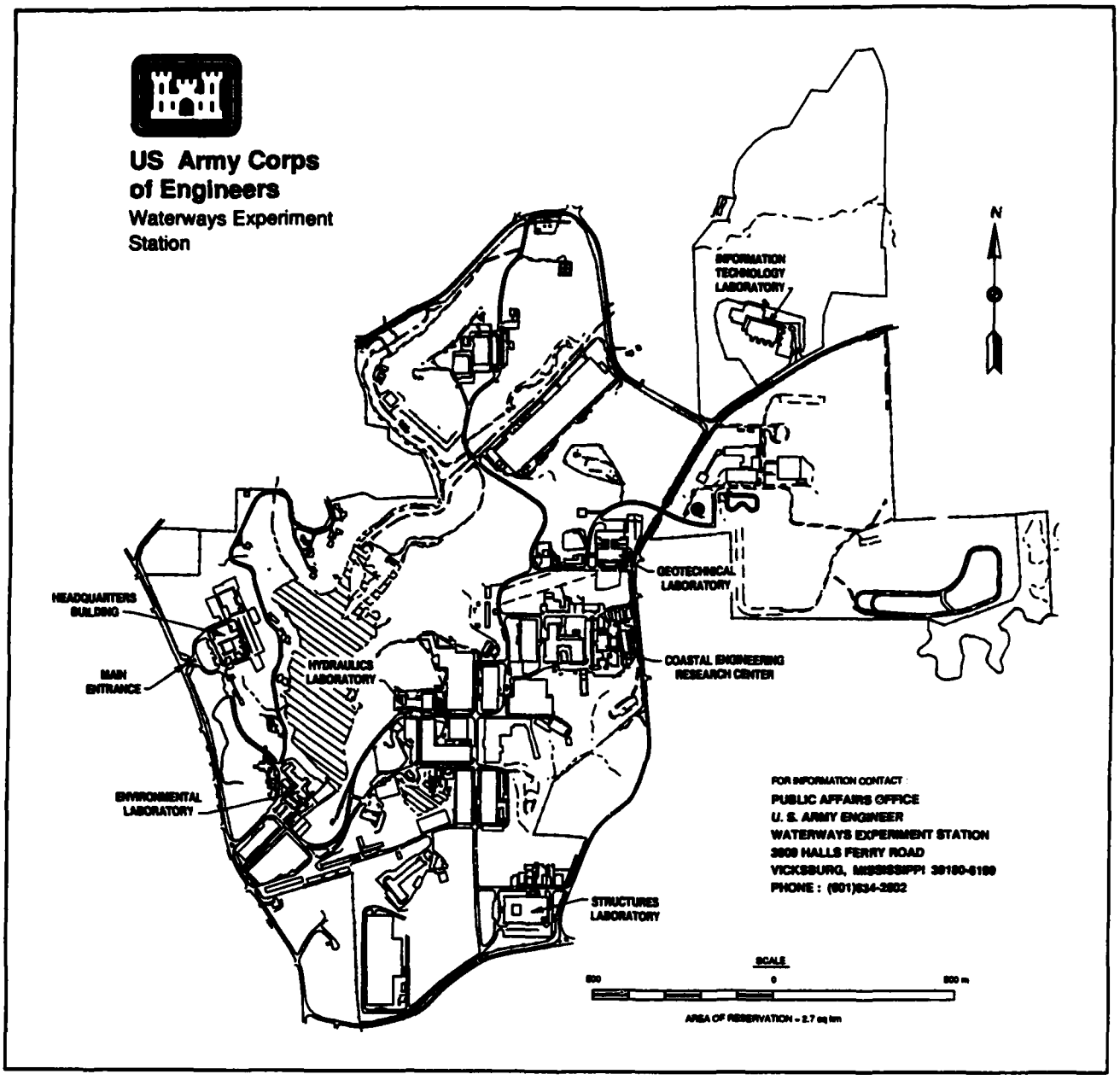


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# Contents

# Preface

In November 1993, the U.S. Army Engineer Waterways Experiment Station (WES) held an International Symposium on Hawaiian Stream Ecology, Preservation, and Management, in Hilo, HI. The purpose was to bring together Federal, state, and private concerns to examine the state of the knowledge on the ecology and management of Hawaiian streams and to establish guidelines and plans for stream preservation.

This symposium was funded by the Operations Division, U.S. Army Engineer District, Honolulu, Pacific Ocean Division, Fort Shafter, HI, with assistance from the State of Hawaii Commission on Water Resource Management, Honolulu, HI.

This report was prepared and edited by Dr. Carl M. Way, Environmental Laboratory (EL), WES. The editor would like to thank those who provided assistance with the symposium: Dr. Albert J. Burky (University of Dayton, Dayton, OH), Mr. Skippy Hau (Department of Aquatic Resources, Maui, HI), Ms. Sallie Edmunds (Commission on Water Resources Management, Honolulu, HI), and Ms. Juliana Harding (University of Dayton).

The report was prepared under the general supervision of Dr. Edwin A. Theriot, Chief, Aquatic Ecology Branch, EL, Dr. Conrad J. Kirby, Chief, Ecological Research Division, EL, and Dr. John W. Keeley, Director, EL. The technical monitor for this report was Mr. Mike Lee, Pacific Ocean Division.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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# Agenda

**Monday, 1 November 1993**

**0830-0945: Registration and packet pickup** - Crown Room, Naniloa Hotel

0945-1000: **Welcome** - Michael T. Lee, U.S. Army Corps of Engineers

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Comparison of visual estimation methods applied in Hawaiian streams
**M.H. Kido, D.E. Heacock, and A.M. Brasher**

1030-1100
Population biology of the endemic Hawaiian stream gastropod, Neritina granosa (Prosobranchia: Neritidae)
**M.H. Hodges**

1100-1130
Computer image-based identification of Hawaiian stream organisms
**W.A. Johnson and C.M. Way**

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Diet of the introduced smallmouth bass, Micropterus dolomieui, in the Wailua and Huleia Rivers, Kauai, Hawai'i: impact on native Hawaiian stream fauna
**D.E. Heacock, K. Berg, and M.H. Kido**

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1300-1330
Rainy season stream benthic algal growth on Hawai'i, Maui, and Oahu
**J.D. LaPerriere**

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Gathering baseline data on stream organisms and stream systems within National Parks in Hawai'i
**A.M. Brasher, L.L. Loope, and M.H. Hodges**

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Population genetics of the endemic Hawaiian stream gastropod, Neritina granosa (Prosobranchia: Neritidae): high gene flow and demographic isolation
**M.H. Hodges**

**Session 2: Biology of Native Gobies**

1430-1500
The use of a modified Breder trap to quantify seasonal upstream migration of goby postlarvae in Iao Stream, Maui
**A.J. Burky, S. Hau, and C.M. Way**

**1500-1530: BREAK**

**Agenda**

1530-1600
The effects of stream channelization on Lentipes concolor and Sicyopterus stimpsoni distribution and abundance on Oahu

**R.A. Englund**

1600-1630
Trophic specialization and morphological adaptation to feeding in native Hawaiian amphidromous freshwater fishes

**M. Pacheco-Agan and M.H. Kido**

1630-1700
Habitat and resource partitioning patterns in three species of endemic Hawaiian gobies, Lentipes concolor, Sicyopterus stimpsoni, and Awaous guamensis

**J.M. Harding, A.J. Burky, C.M. Way, S. Hau, and W.K.L.C. Puleloa**

1700-1730
Retrospective analyses of Hawaiian freshwater gobies: Impact on stream ecology, preservation, and management

**R.L. Radtke**

**1730-1930: DINNER**

1930-2000
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**C.M. Way, A.J. Burky, S. Hau, and J.M. Harding**

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**S. Hau**

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**Session 3: Stream Management and Preservation**

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**M.R. Kolman**

**Agenda**

0900-0930
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**W.S. Devick**

0930-1000
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**M.T. Lee**

**1000-1030: BREAK**

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**M.A. Ridgley and D.C. Penn**

1100-1130
Multicriterion analysis and the problem of setting instream flow standards: 2. A multiobjective programming model

**M.A. Ridgley**

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**D.W. MacDougal**

**1200-1300: LUNCH**

1300-1730: **Open Discussion:** The future of Hawaiian stream management

**Dick Cox, Moderator**

1300-1420: How to develop biological criteria for stream protection?

Panel: **C.M. Way**, U.S. Army Corps of Engineers, Waterways Experiment Station and
**A.J. Burky**, Department of Biology, University of Dayton
Scientific criteria for Hawaiian stream preservation and management
**A. Yuen**, U.S. Fish and Wildlife Service
**W.S. Devick**, Hawai'i State Division of Natural Resources

**1420-1430: BREAK**

1430-1550: How can a partnership be formed between scientists, water managers, and policy makers to manage and protect Hawaiian streams?

Panel: Members to be announced

**1550-1600: BREAK**

1600-1730: The future of Hawaiian streams: Integrating values

Panel: Members to be announced

1730-1800: **Closing remarks** - Dick Cox, Hawai'i State Water Commission

## Agenda

**Wednesday, 3 November 1993**

0900-1500
Field trip to Hakalau, Pahoehoe, and Kolekole Streams

# Session 1

# General Stream Ecology

## Comparison of visual estimation methods applied in Hawaiian streams

Michael H. Kido[1], Donald E. Heacock[2], and Anne M. Brasher[3]

[1]Environmental Research Group, University of Hawai'i-Kauai Research Facility, 7370-A Kuamoo Road, Kapaa, HI 96746-9327
[2]Division of Aquatic Resources, DLNR, 3060 Eiwa Street, Room 306, Lihue, Kauai, HI 96766
[3]National Park Service, 192 Kapuahi Street, Makawao, Maui, HI 96768

Three generalized underwater visual estimation methods (line quadrat, fixed quadrat, timed quadrat) are currently being used in Hawaiian streams to estimate abundance and densities of native amphidromous fish species. Using ANOVA (SAS Institute, Inc. 1989), data from replicated estimation trials were analyzed to evaluate the three methods for variability in accuracy and precision (second stage errors) as well as cost-effectiveness. The analysis suggests that experienced divers add small between-diver variance to the estimates, that the line quadrat method was most accurate, and that fixed and timed methods usually gave higher mean counts of fish. Differences in fish densities between site influenced the estimates of both timed and fixed methods (first stage errors). Suggestions are presented as to the sources of the observed variation, correction terms between method, and applicability to expanded ecological sampling schemes.

**1030-1100**

## Population biology of the endemic Hawaiian stream gastropod Neritina granosa (Prosobranchia: Neritidae)

Marc H. Hodges

Haleakala National Park, P.O. Box 369, Makawao, Maui, Hawai'i 96768

Reproduction, recruitment, and population structure of the endemic amphidromous gastropod Neritina granosa Sowerby (Prosobranchia: Neritidae) were surveyed in three Maui streams during July, August, and September, 1991. As observed by earlier workers, physiographic features and stream flow appear to influence upstream migration behavior. Reproduction varied greatly among streams and was correlated to adult biomass. Recruitment also varied among streams and may be a function of larval mortality or ease of stream entry. Changes in reproduction and recruitment were correlated among streams, suggesting environmental cues that operate across nearby catchments. Population structure differed strongly among streams. Comparing data with that of an earlier worker showed population structure to differ markedly through time. The observed changes in population structure reflect changes in instream conditions through time and/or recruitment history. Efforts to establish management strategies or instream flow standards must take account of recruitment variability and its potential effect on population structure.

**1100-1130**

## A microcomputer-based, digital identification key for Hawaiian stream organisms

William A. Johnson[1] and Carl M. Way[2]

[1] Department of Biology, Nicholls State University, Thibodaux, LA 70310
[2] USAE Waterways Experiment Station, Vicksburg, MS 39180

Field personnel working with state and federal agencies concerned with the conservation of natural resources are frequently faced with the task of identifying organisms under less than optimal conditions. The problem is even more severe on tropical islands where faunal life histories are often incompletely known. Exacerbating the problem is the fact that many such personnel lack the training necessary to successfully use the identification aids provided by professional taxonomists, as such aids require a great deal of technical expertise and familiarity with taxonomic jargon. We have attempted to address this problem by developing an image-based computer identification system for organisms of selected Hawaiian streams. The "key" was developed on a 24-bit capable Macintosh™ computer, a TrueVersion NuVista+™ video capture card, and both Sony and JVC RGB video cameras. The key has the capabilities of displaying artist-enhanced digitized video images of photographic quality, artist-rendered images of structural features essential to the identification of the organisms, and accompanying text describing the distribution, abundance, and ecology of the life stages of known organisms inhabiting streams of the Hawaiian islands. The key can be used by researchers and technicians while they are sitting at the microscope examining "real" organisms. While the current system is very useful, another technology, the computer-based expert system, offers even more effectiveness in identification. We plan to implement an image-based computer expert system incorporating even higher quality images (scanned 35 mm slides and slides transferred to the new Kodak PCD format) for the identification of these same organisms. Expert systems offer greater flexibility because they make "calls" on characters stored in a database, freeing the user to exercise his/her discretion in selecting from the character database. In the existing system, the user is "locked-in" to a specific routine. Thus, the expert system approach has the potential to save the user time. Expert systems can also incorporate verification routines which provide the user with a greater level of security than in systems lacking verification. Finally, characters can be assigned "weights" in an expert system, providing assistance to the user when he/she is working with gropus exhibiting a wide range of variation.

**1130-1200**

# Diet of the introduced smallmouth bass Micropterus dolomieui, in the Wailua and Huleia rivers, Kauai, Hawai'i: Impact on native Hawaiian stream fauna

Donald E. Heacock[1], Kristina Berg[2], and Michael H. Kido[3]

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With the aim of verifying the impact of the alien smallmouth bass on the native Hawaiian stream fauna, bass were captured and their stomach contents analyzed in order to identify and quantify prey items. Examination of gut contents from 42 smallmouth bass ranging in size from 12.5 to 35.0 cm (SL) revealed that this alien predator feeds on three endemic, amphidromous, species: one goby (Awaous stamineus) and two crustacea, a palemonid shrimp (Macrobranchium grandimanus) and a caridean shrimp (Atyoida bisulcata). Additionally, larvae of the endemic Odonata damselfly (Megalagrion) and larvae of the alien Trichoptera caddisfly (Cheumatopsyche analis) were also preyed upon by smallmouth bass.

Because smallmouth bass are opportunistic carnivores and are well-adapted to ambient stream conditions which exist in Hawaiian streams with moderate to high water quality, the potential anthropochore dispersal of this alien species from one watershed to another poses a significant ecological threat to the native stream biota on Kauai. Smallmouth bass have already expanded their range outside of the watershed where they were originally introduced, and considering the recorded impact of anthropochore dispersal of predatory game fish it may be necessary to control the geographic range of this species in the near future.

1300-1330

## Rainy season stream benthic algal growth on Hawai'i, Maui, and Oahu

Jacqueline D. LaPerriere

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Fairbanks, Alaska 99775-0110

In February and March 1990, I examined benthic algae and factors that influence them in each of four streams on Oahu, Hawai'i, and Maui. The streams were chosen because the were of moderate to high quality, undiverted, small enough to wade for discharge measurements, and accessible by road (though remote enough to control vandalism of instruments left in place). One stream, Waikapu on Maui, was later eliminated from the data analysis because it was a diverted stream. The chosen streams were also selected to vary in alkalinity as widely as possible, since carbon is the element that is most required in photosynthesis. Algal growth rate was immeasurably low in all but four streams using the Odum open-water diurnal-oxygen method. Standing crop of benthic algae as chlorophyll a correlated significantly with the alkalinity and total nitrogen of the stream. Nitrogen to phosphorus ratios for most (and probably all) of the streams were low enough to suggest possible nitrogen limitation of algal growth (if either of these two nutrients was limiting). Further research on the relative importance of nitrogen and phosphorus to Hawaiian stream benthic algae should be conducted. In-stream stimulation bioassays with nutrient-augmented artificial substrates would probably be the best approach. Total nitrogen and total phosphorus varied together among the studied streams, and both were highest in streams affected by human activity ranging from agriculture to housing subdivisions. During and following freshets, turbidity and color were elevated in streams studied for light penetration. The amount of light extinction down through the water column was modeled from measurement of water color or turbidity. The effects of sediment entering streams uncontrolled during storms can be estimated, therefore, from simple turbidity measurements. Sediment control is suggested as a best management practice for protecting Hawaiian stream benthic algae from reduced light and from non-point source enrichment by phosphorus since phosphorus is usually a significant component of volcanic soils.

**1330-1400**

## Gathering baseline data on stream organisms and stream systems within national parks in Hawai'i

Anne M. Brasher[1], Lloyd L. Loope[2], and Marc H.D. Hodges[2]

[1] University of California at Davis
[2] Haleakala National Park, P.O. Box 369, Makawao, Maui, Hawai'i 96768

Two of Hawai'i's national parks have significant stream systems. Palikea Stream in Haleakala National Park on the island of Maui drains Kipahulu Valley, the largest watershed on Maui. The upper 75% of this watershed is nearly pristine; the lower portion is impacted by feral pig digging, cattle grazing, and perhaps also by locally heavy use by humans for swimming. No water is removed from this stream. Waikolu Stream, the largest drainage in Kalaupapa National Historic Park on the island of Moloka'i, is heavily impacted by water removal in its upper reaches. The National Park Service, which has a mandate for ecosystem protection and preservation of biological diversity, has begun gathering baseline data on organisms and habitat quality within these two streams. Initial data gathering is planned at quarterly intervals over a two year period. Organisms being monitored include three endemic gobiid fishes; 'o'opu alamo'o (Lentipes concolor), 'o'opu nopili (Sicyopterus stimpsoni), and 'o'opu nakea (Awaous stamineus), and an endemic decapod crustacean; 'opae kala'ole (Atyoides bisulcata), and an endemic neritid mollusc; hihiwai (Neritina granosa). The alien prawn Macrobrachium lar, which appears to exert a negative impact on native stream organisms, is being monitored in Palikea Stream. In addition, surveys of the aquatic insect fauna are being conducted, with benthic and drift patterns identified. Water quality parameters, including oxygen, nitrogen, pH, phosphate, turbidity, hardness, and alkalinity are being measured three times per year to determine diel and seasonal variation. The rationale for baseline inventory and monitoring in Hawai'i's national parks is that the National Park Service needs to know what resources are in the park, both terrestrial and aquatic, and to have the capacity of periodically reassessing the status of these resources. The agency needs to evaluate how well the mandate for ecosystem protection and preservation of biological diversity is being met and to design management strategies to meet the mandate as conscientiously as possible.

1400-1430

## Population genetics of the endemic Hawaiian stream gastropod, Neritina granosa (Prosobranchia: Neritidae): high gene flow and demographic isolation

Marc H. Hodges

Haleakala National Park, P.O. Box 369, Makawao, Maui, Hawai'i 96768

Protein electrophoresis was used to study the population genetics of the endemic Hawaiian freshwater amphidromous gastropod Neritina granosa Sowerby (Prosobranchia: Neritidae). Samples were taken from twelve streams located throughout the Islands during July, August, and September, 1991. We found significant genetic heterogeneity (Fst = 0.034), but no obvious geographic structure to allele frequency differences among populations. Because genetic homogenization requires few migrants and can be independent of population size, the metapopulation can be essentially panmictic at the same time large populations remain 'demographically isolated'. Thus despite a planktonic larval stage and high gene flow, it is possible that very few individuals within large populations of N. granosa are migrants. The distinction between genetic and demographic isolation has application in marine ecology and conservation where populations are large and dispersal potential high.

# Session 2

# Biology of Native Gobies

**1430-1500**

## The use of a modified Breder trap to quantify seasonal upstream migration of goby postlarvae in Iao Stream, Maui

Albert J. Burky [1], Skippy Hau [2], and Carl M. Way [3]

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[3]USAE Waterways Experiment Station, Vicksburg, Mississippi 39180

A Breder trap design was modified by down scaling to a 7.6 by 15.2 cm acrylic box, placing 0.5 mm standard sieve mesh at the blind end to allow downstream flow to pass through the system, and placing a 0.6 mm vertical opening at the base of the guide funnel. Traps were secured with rocks and/or nylon rope to maintain instream flow orientation. The Breder traps are being used to assess both diurnal and seasonal migration of goby postlarvae in Iao Stream, Maui. The study site is located in a modified concrete stream channel ca. 200 meters from the stream mouth. Three major stream diversions above the study area create intermittent stream conditions which reduces the success of gobies migrating upstream. During April 1993, there was a distinct diurnal periodicity to postlarval migration with movement starting at dawn and stopping at dusk with a broad peak in numbers from mid-morning to mid-afternoon, with numbers ranging from <1 to > 6 postlarvae per trap hour. The gobies Lentipes concolor, Sicyopterus stimpsoni, and Awaous guamensis followed the same general diurnal pattern with densities ranging from < 1 to > 2.5, < 1 to > 3, and < 1 to > 1.5 postlarvae per trap hour, respectively. There was also a distinct seasonal pattern to postlarvae migration. Densities of postlarvae ranged from 0 in June and September to 20 per trap hour in May. Densities for the three goby species followed the same general pattern. The mean standard body length of migrating postlarvae was not significantly different within a species from April to September 1993 (14.0 mm for L. concolor, 22.1 mm for S. stamineus, and 15.8 mm for A. guamensis). The historic pattern of seasonal discharge for Iao Stream is similar to that of other Hawai'i streams with April and November being historically 'wet' and September being historically 'dry.' It has been shown that instream reproduction and downstream movement of larvae of L. concolor is synchronous with the seasonal periods of wet and dry. It is probable that upstream migration of L. concolor postlarvae is also periodic coinciding with the overall reproductive cycle of instream populations. The use of knowledge on downstream and upstream movement of larval/postlarval gobies may be an important indicator of the recruitment capacity of a stream.

# The effects of stream channelization on Lentipes concolor and Sicypoterus stimpsoni distribution and abundance on Oahu

Ronald A. Englund

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The Hawaiian archipelago includes five high islands with 376 streams supporting five species of amphidromous fishes and many native invertebrates. The island of Oahu represents less than 10% of the combined land mass of the high islands, while approximately 80% of the human population lives within its shores. On Oahu, freshwater stream habitats have been far more extensively altered by diversion, channelization, alien species introductions, and other consequences of human activity than on the other islands. Contrary to perceptions of as recently as 1990, the Island of Oahu does contain a complete assemblage of native endemic Hawaiian stream 'o'opu. However, on Oahu all five endemic Hawaiian stream fishes are less widely distributed and abundant than on the other islands. The significance of these human activities on the native aquatic biota has until recently largely been ignored. The results of this ongoing study indicate that Sicypoterus stimpsoni was found in 11 surveyed streams, with Lentipes concolor being found in 8 surveyed streams. Whether this difference reflects a greater sensitivity of these species to stream alteration, a naturally lower suitability of Oahu streams for L. concolor, or an inadequate effort in surveying higher stream reaches on this island is presently unknown. However, L. concolor has not yet been found in channelized streams on Oahu, even though some of these channelized streams contain high densities of other native 'o'opu such as Awaous stamineus in the upper elevational areas. S. stimpsoni was found in only one of eleven channelized streams surveyed.

1600-1630

# Trophic specialization and morphological adaptation to feeding in native Hawaiian amphidromous freshwater fishes

Melissa Pacheco-Agan[1] and Michael H. Kido[2]

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Morphological variation in feeding traits observed among native Hawaiian stream fishes suggests some separation in trophic niche exploited by each species. Traits compared were mouth structures, gill raker morphology, gut convolution, and gut length to body length ratios. Variation in these morphological traits were compared to data on food composition determined through gut analysis. Highest mean gut length to body ratios were determined for the predominantly herbivorous, Sicyopterus stimpsoni Gill while the carnivorous Eleotris sandwicensis (Vaillant and Sauvage), had the lowest mean. For S. stimpsoni, the data indicates that growth of the digestive system is allometric and that a linear relationship exists between gut length and body length. No significant differences in gut length to body length ratio between sex or sites sampled were determined by ANOVA for S. stimpsoni; however ratios were significantly lower (p=.0001) for fish under 45 mm in standard length.

# Habitat and resource partitioning patterns in three species of endemic Hawaiian gobies, Lentipes concolor, Sicyopterus stimpsoni, and Awaous guamensis

Juliana M. Harding[1], Albert J. Burky[1], Carl M. Way[2],
Skippy Hau[3], and William K.C.L. Puleloa[4]

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Habitat and resource use patterns were evaluated for endemic Hawaiian gobies to better understand the trophic structure of Hawaiian streams. Lentipes concolor, Awaous guamensis and Sicyopterus stimpsoni are sympatric near the mouths of most streams and at higher elevations where the streams are continuous cascades (Waikolu Stream, Moloka'i and Palauhulu Stream, Maui). L. concolor is often the only native fish at higher elevations above numerous high waterfalls (Kahakuloa and Makamaka'ole Streams, Maui; Pahoehoe Stream, Hawai'i). Overall food availability and habitat use in these streams are controlled by the magnitude and intensity of stream flow. Instream observations indicate that L. concolor and S. stimpsoni prefer areas with heterogeneous hard substrate, while A. guamensis are found in a range of substrate types. Data on gut morphology and contents for individual L. concolor, S. stimpsoni, and A. guamensis were used to classify these species into three feeding groups. The ratio of gut length (GL) to total body length (BL) is indicative of the processing time required for prey items. Herbivores require the longest gut processing time; carnivores, the shortest; omnivores, intermediate processing times. In habitats where all three species are sympatric (lower reaches of Waikolu, Kahakuloa, and Palauhulu Streams) and in habitats without sympatric species (upper reaches of Makamaka'ole and Pahoehoe Streams), L. concolor have mean GL/BL ratios of 0.63, 0.69, 0.62, 0.79, and 0.74, respectively. These data suggest intraspecific population differences for L. concolor that reflect differences in trophic structure and/or habitat condition. S. stimpsoni from Waikolu and the mouth of Makamaka'ole Stream have mean GL/BL ratios of 2.7. Waikolu A. guamensis have a mean GL/BL ratio of 1.18. Examination of gut contents for all species corroborates the categorization of L. concolor as a carnivore, S. stimpsoni as a herbivore, and A. guamensis as an omnivore. Since plant material is not as reliably quantified as macroinvertebrates, the ratio of total number of aquatic invertebrates (AI) to individual gut volume (GV; $cm^3$) is used as an index of gut content. L. concolor's mean AI/GV ratios from Waikolu, Kahakula, and Palauhulu Streams are 774, 222, and 6731 AI/$cm^3$, respectively. Mean AI/GV ratios from L. concolor populations from the upper reaches of Makamaka'ole and Pahoehoe Streams, are 1787 and 2696 AI/$cm^3$, respectively. In contrast, S. stimpsoni and A. guamensis from Waikolu Stream have mean AI/GV ratios of 22 and 3 AI/$cm^3$, respectively. S. stimpsoni from the mouth of Makamaka'ole Stream has a mean AI/GV ratio of 10 AI/$cm^3$. An understanding of resource partitioning and habitat use based on data will help provide objective criteria for management decisions regarding Hawaiian streams.

## Retrospective analyses of Hawaiian freshwater gobies: Impact on stream ecology, preservation, and management

Richard L. Radtke

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There continues to be a lack of information on the life history patterns, both on a daily and diadromous basis for Hawaiian freshwater gobies. Fish life-history data, including diadromous migration patterns provide essential data for population dynamic analyses and contribute directly to decision-making in habitat preservation and management. In the present investigation we review the current information on life-history characteristics and migration patterns of Hawaiian freshwater gobiod species. For selected species of Hawaiian freshwater gobies, we derive environmental patterns on a daily and diadromous basis and interpret these results in terms of general management strategy for Hawaiian freshwater gobies.

The examination of variables influencing survival and migration has been augmented by dramatic advances in the study of microstructural and chemical patterns in fish otoliths; structures that effectively serve as storage sites of chronological environmental information. Otoliths are calcium carbonate concretions found in the inner ears of teleost fishes. The otoliths of fishes have incorporated within their structural and chemical components a large amount of life history and physiological information. This information is revealed when appropriate analytical methods, based on an understanding of the mechanisms underlying changes in structure and chemistry of otoliths, are utilized. External and internal examinations of otoliths for macrostructure and microstructure by light and scanning electron microscopy (SEM) can be used to estimate the age of adult, juvenile and larval fishes. Integrating chemical analyses and SEM examinations of increments in the same otolith, can make it possible to reconstruct the daily environmental history for an individual fish. Chemical composition of otoliths is controlled by the physiological activity of fish, which in turn is affected by environmental conditions. Strontium/Calcium ratios in otoliths appear to be temperature dependent and microprobe techniques make it feasible to interpret daily changes in elemental composition. The present research offers a new approach to the evaluation of critical periods in the life histories of gobies. Microstructural otolith analyses, in addition to strontium/calcium concentration ratios measured at various positions in the otoliths, provide a reliable indication of past environmental conditions, and enable an estimate of spawning sites, life history movements, and distributions of freshwater gobies in Hawai'i. The research presented provides critical environmental history and migrational information for Hawaiian freshwater gobies. In a management sense, such information is important to our understanding of the processes underlying recruitment and growth rates and makes it possible to link growth and mortality rates to nutritional and environmental occurrences.

## Feeding of the endemic goby, Lentipes concolor, in relation to invertebrate drift and benthic communities, and parasitic infection of native fishes with the nematode, Camallanus sp., in Hawaiian streams.

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Lentipes concolor is one of the top native instream predators, and except for introduced exotics, the only native fish at higher elevations above numerous waterfalls. L. concolor from Makamaka'ole Stream were collected bimonthly or monthly during 1990-1992. Guts were dominated by chironomids (0-1224/gut) followed by atyid shrimp (0-97/gut), ancylid limpets (0-18/gut), tricopterans (0-14/gut), odonates (0-13/gut), oligochaetes (0-8/gut), and lepidopterans (0-2/gut). We have often observed L. concolor feeding on drift. However, benthic invertebrates composed a significant portion of the diet since odonates and ancylid limpets were commonly eaten but were usually absent from drift samples. Additionally, guts were often filled with diatom frustules, filamentous algae and micro-chironomid larvae which are characteristic of epiphytic benthic communities. Often guts were empty which coincided with periods following prolonged high stream flows. Drift densities in Makamaka'ole Stream have been reduced 10-fold and bottom substrates have been denuded of benthic organisms after a major storm (> 5000 cfs). In several instances the guts of male L. concolor were filled with L. concolor eggs and/or larvae. Our data indicates that L. concolor is an opportunistic carnivore feeding on drift and benthic macroinvertebrates. It is probable that food availability is controlled by invertebrate life cycles as well as stream flow. The guts of gobies can also be infected by the parasitic nematode, Camallanus sp. These parasites can exceed one cm in length and are attached to the rectum wall by hooked mouth parts. Camallanus sp. was not observed in L. concolor from Palauhulu and Waikolu Streams, but occurred in 73%, 100% and 67.3% of all fish examined from Pahoehoe, Kahakuloa and Makamaka'ole Streams, respectively. The mean infection of nematodes was 7.0, 5.7, and 6.6 per female fish, and 5.0, 13.5, and 5.6 per male fish for Pahoehoe, Kahakuloa, and Makamaka'ole Streams, respectively. Nematode presence was also confirmed in specimens of L. concolor from Honolii Stream, Hawai'i and Iao Stream, Maui; Sicyopterus stimpsoni and Awaous guamensis from Makamaka'ole Stream, Maui; and Stenogobius hawai'iensis and Eleotris sandwicensis from Maliko Stream, Maui.

## The distribution and abundance of native gobies within Hawai'i's largest river, the Wailuku River, Hawai'i Island

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Seven large-scale sampling efforts were made on the mainstem Wailuku River and four of its major tributaries upstream of Rainbow Falls (ca. 400 ft. elevation) between September, 1990 and August, 1993. On three occasions two reaches within the mainstem Wailuku River below Rainbow Falls were also sampled. Sampling reaches consisted of from 0.5-1.25 miles of stream, and encompassed the range of habitat types present within the system. Each sampling effort comprised 80-100 man-hours of snorkeling observation time allocated among the 8-10 stream reaches. Three of the five native gobies have been observed within the Wailuku River system: 'o'opu alamo'o, 'o'opu nopili, and 'o'opu nakea. Rainbow Falls appears to be the cause of a marked discontinuity in goby distribution within the system. Below this falls, 'o'opu nakea is tremendously abundant, and 'o'opu nopili is moderately abundant. No 'o'opu alamo'o have been observed within this area. In contrast, with the exception of a handful of sightings of 'o'opu nopili, 'o'opu alamo'o is the only native fish we have observed above Rainbow Falls. Overall, in fact, the density of native fishes above Rainbow Falls is remarkably low, with total counts during individual 10-14 man-hour sampling efforts ranging from 0 to only 98 fish. Even so, the abundance distribution of 'o'opu alamo'o above Rainbow Falls is markedly clumped, with mean counts for different reaches ranging from 2 to 60.

# A simulation model of the reproductive biology of the goby, Lentipes concolor, from Makamaka'ole stream, Maui

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There is persistent pressure in Hawai'i for the development of aquatic resources resulting in increasing concern over the future of the many endemic fauna that are found in freshwater streams including the threatened goby, Lentipes concolor. L. concolor has a diadromous life cycle in which juveniles have some obligatory period of oceanic development. The migration cycles of both larvae and juvenile L. concolor require a stream which flows to the ocean for the critical reproductive periods. This requirement for stream flow makes the species particularly sensitive to any instream perturbations such as the construction of diversions or dams. A knowledge of the potential impacts of these activities on the ecology of L. concolor is crucial for sound management decisions. We have developed a population-level simulation model to assess the dynamics of reproduction in Lentipes concolor. The model predicts the number of reproductive females for a given stream reach and is based upon three years of field data from Makamaka'ole Stream, Maui on the seasonal occurrence of L. concolor larvae in the drift, female reproductive biology, and current and historic patterns in stream hydrology. The model is successful in predicting realistic values for the densities of female L. concolor found in Makamaka'ole Stream under normal stream flow conditions. The model predicts that any changes in stream flows which reduce overall levels of discharge and/or alter the seasonal periodicities in discharge significantly reduce the population size of L. concolor. The model can hopefully be used to learn more about the interactions between the ecology of L. concolor and its physical habitat.

**2100-2130**

# Postlarval migration of the native gobies, Lentipes concolor, Awaous guamensis, and Sicyopterus stimpsoni on a terminal waterfall in Ke'anae on the island of Maui

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Between August 1991 and August 1993, postlarvae of three amphidromous fish species known in Hawai'i as 'o'opu (Gobiidae) were collected during their upstream migration on the face of a four-meter terminal waterfall. The location is in Ke'anae on the windward or northeast side of Maui, approximately 100 meters from the Pacific Ocean. More than 333 million liters (88 MG) per day are diverted from Palauhulu and Pi'ina'au Streams which join just above the waterfall study site. 'O'opu migrated throughout the year and were collected with a fine mesh aquarium net. More than 350 fish were identified and standard body length measurements were recorded. 'O'opu 'alamo'o (Lentipes concolor ) made up 55% of the total number of migrating fish and were between 13.0 and 16.5 mm in length. 'O'opu nakea (Awaous guamensis ) represented 33% of the migrating fish and were 14.0 to 37.0 mm in length. 'O'opu nopili (Sicyopterus stimpsoni ) accounted for 11% of the total and ranged from 21.0 to 26.0 mm. 'O'opu nakea may stay in the estuary to grow before migrating upstream. The larger juvenile sizes and the dark color pigmentation confirmed this growth and development from the normally clear post larvae recruiting from the ocean. L. concolor, A. guamensis, and S. stimpsoni reached maximum densities of 51.7, 20.0, and 8.3 fish $m^{-2}$, respectively, on the waterfall face. There were distinct seasonal patterns to postlarval migration. L. concolor postlarvae migration was highest during those months with historically high stream flows. These data are important for understanding the seasonal recruitment patterns of instream populations and for the rational planning/management of water resources.

# Session 3

# Stream Management and Preservation

# Development and application of a GIS for preservation and management of endangered species in Hawaiian streams

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Preservation of stream-related resources is a major challenge in many parts of the world. This is especially true in the tropics, such as Hawai'i, where year around climatic conditions suitable for agriculture and tourism subject streams to constant threat from agricultural chemicals and other man-made pollutants. There is an urgent need for a natural resource management system for economically competitive and environmentally sound utilization of stream resources. The use of the GIS technology is ideally suited for management and utilization of spatially complex stream ecosystems. This paper describes the development and utilization of a GIS for preservation and management of Hawaiian streams.

Preliminary research activities related to the spatial and temporal analysis of this study are summarized. The activities center on data compilation and implementation of an automated Geographic Information System (GIS) for use in identifying and analyzing habitat for the Hawai'i stream species within the Island of Kauai, HI. Essential GIS data layers, including a land use and land cover classification system, elevation, rainfall distribution, soils, and streams and road network for use with the insect habitat analysis, are identified and included in the system. The stream species field data were stored and manipulated using Hawai'i Natural Resource Information System (HNRIS) software developed by the Agricultural Engineering Department of the University of Hawai'i. Procedures of digitizing, processing, and analyzing stream species data are described and the potential of GIS technology for use in investigating and managing steam species habitat are illustrated through numerous examples.

**0830-0900**

## The small watershed program in Hawai'i

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The Watershed Protection and Flood Prevention Act of 1954 has spawned over 1500 small watershed projects nationally. In Hawai'i there are five completed and six currently authorized projects. As this program approached its fortieth year of existence, it has evolved into a flexible and responsive mechanism to effectively manage water resources and protect watersheds. The Soil Conservation Service Watershed Program provides a significant opportunity to bring together a wide range of interests striving to balance economic, social and environmental needs through a holistic approach to watershed management. Agricultural, developmental, native Hawaiian, and environmental interests are converging today and the program managers, supporters, and beneficiaries are challenged to prove the viability of the SCS Watershed Program.

# A Summary of the Stream Management Program of the Division of Aquatic Resources, State of Hawai'i

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Adoption of the State Water Code in 1987 created a need for reliable information about Hawaiian stream biota to support the decision-making process of the Board of Land and Natural Resources and the newly established Commission on Water Resource Management and to improve protection and management of related native freshwater fisheries. Although stream fishes and macroinvertebrates are deeply linked with Hawaiian cultural history and have provided valued recreational fisheries to the present day, the view prior to the Water Code that all surface waters were privately owned provided a disincentive to sufficient attention at the State level. In 1989 the Division of Aquatic Resources initiated efforts to improve the knowledge base about streams and their associated biota and focused on an ecosystem approach, as contrasted to single-species management. The immediate steps taken were to expand biological reconnaissance surveys and to develop improved quantitative survey procedures. Concurrently, it was recognized that active Hawaiian stream research scientists should be brought together to summarize the most recent findings and to provide a forum for the exchange of ideas. With the cooperation of various governmental agencies, including especially the Corps of Engineers, an invitational symposium was held in 1990. The symposium contributed to development of a stream management and protection plan that was implemented by the Division in 1991. General structure of the plan involves definition of the distribution and abundance of stream biota, primarily by Division personnel, and associated basic research to help explain these findings, primarily by qualified outside scientists who are funded through the program. Seven staff biologists and a variable number of technicians are involved in the program. Progress has been rapid in certain areas, but many fundamental questions have yet to be answered before our understanding fits together in the targeted ecosystems context. Support of basic research will continue to be emphasized. Some shifts in direction have occurred in response to new findings and unexpected perturbations, most dramatically Hurricane Iniki last September. More attention will be given to stream restoration in the near future, partly because various studies to date are now suggesting that significant improvements can be made by "tweaking" systems in streams that have not yet been completely devastated by major channelization or equivalent modifications.

**0930-1000**

## Potential non-applicability of Instream Flow Incremental Methodology hypothesis to Hawaiian goby, Lentipes concolor

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The Instream Flow Incremental Methodology (IFIM) was applied in Hawaiian streams in an effort to establish conservation flows for stream diversion projects, but the IFIM hypothesis and presumptions were not verified or validated for use in torrential Hawaiian streams. Analysis of stream flow variability and measurements of stream velocities at the 2 mm spatial scale were applied to test IFIM hypotheses and presumptions. Results suggest that Hawaiian stream organisms, particularly, Lentipes concolor, are not sensitive to stream flow as hypothesized in IFIM, and that Hawaiian stream organisms are not sensitive to flow variables used in IFIM. Hawaiian stream organisms may be responding to stream flow on a larger, macro level.

**1030-1100**

## Multicriterion analysis and the problem of setting instream flow standards: 1. Issues, concepts, and tasks

Mark Ridgley and David Penn

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Setting instream flow standards (IFS)-- the amount of flow to be left in a stream channel--is a difficult multidimensional problem facing water managers everywhere. The difficulties arise from the fact that while the oft-stated purpose of IFS is to protect *instream values*, for any given stream it is neither obvious what such values are nor how best to measure them. For example, particular challenges stem from uncertainties in relationships between streamflow and biota. What's more, not only will those values conflict with each other, they will also conflict with other values related to the diversion and use of water out of the channel. Finally, setting IFS is a public-sector problem in which multiple decision makers, multiple stakeholders, and a plurality of values prevail, all within a context of considerable uncertainty.

This paper conceptualizes the task of setting IFS as a multicriterion problem and discusses the development of a multicriterion approach into a general IFS methodology. Although designed to be of general applicability, the approach is motivated by the context of Hawai'i, whose Commission on Water Resource Management has been charged with setting such standards, potentially for more than 360 perennial streams. The procedure integrates the use of value trees, multiattribute assessment, and interactive multiobjective programming.

**1100-1130**

## Multicriterion analysis and the problem of setting instream flow standards: 2. A multiobjective programming model

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In the first of this two-paper set, some of the fundamental issues, concepts, and tasks relevant to applying multicriterion analysis to the instream-flow problem were described. One of those elements was the design and use of a multiobjective optimization model for determining the portion of streamflow to allocate to the channel. In this paper, that model, based on recent ideas and developments in interactive, goal, and fuzzy/stochastic programming, is described in detail. A small example, hypothetical yet based on Hawai'i's situation, illustrates the procedure.

## The feasibility of a "conservation reserve" in the context of a proposed hierarchy of stream uses

Douglas W. MacDougal

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Management of streams requires management of the rights of those persons who may claim a legal interest in stream waters, as well as of the instream "rights" of inherent protection given by Article XI of the Hawai'i Constitution. The interrelationship and application of those rights are presently in a state of confusion under the Hawai'i Water Code and Hawai'i decisional law. A methodology is proposed for sensibly dealing with such rights. This methodology divides all uses into two classes: Reserved and Conditional. Reserved uses are those which are guaranteed by the Constitution of the State of Hawai'i and the present Water Code. They consist first of a "Conservation Reserve" which is the assurance of that amount of water which must remain in the stream in order to assure the biological health of the stream. Next, "Indigenous Reservations" (traditional and customary Hawaiian rights, appurtenant rights, and reservations for Hawaiian Homes Lands) are treated on equal parity. Finally and last in priority among the Reserved Uses are "Existing Riparian Uses" in place as of the 1978 amendment to the Hawai'i Constitution. The above Reserved Uses are prior to any other uses and are unaffected by any "balancing of interests" analysis. Conditional uses are those which follow Reserved Uses. In this category, there does exist a balancing of interests between "optimal" stream flows deemed necessary for aesthetic, scenic, recreational and other uses, and out-of-stream diversions. One question here is whether it is possible to base policy on the concept of a "healthy" stream, on which the initial Conservation Reserve is based, and whether such a priority-based method can exist in the absence of more complete scientific quantification of stream flows than now exists. This methodology is compared with others currently under consideration which appear (because of absence of better data) to categorize streams in bulk in a kind of *triage* process. The question is raised, finally, of what kind of data can be made practically available to policymakers to make such a scheme workable if it were to be incorporated into the law of the State of Hawai'i.

# Open Discussion

## The future of Hawaiian stream management

**Open Discussion** **Tuesday, 2 November 1993**

**1300-1420**

**Panel Discussion**: How to develop biological critera for stream protection?

Panel: **C.M. Way**, U.S.Army Corps of Engineers, Waterways Experiment Station
**A.J. Burky**, Department of Biology, University of Dayton
**A. Yuen**, U.S. Fish and Wildlife Service
**W.S. Devick**, Hawai'i State Division of Natural Resources

**Open Discussion** **Tuesday, 2 November 1993**

**1300-1315**

## Scientific criteria for Hawaiian stream preservation and management

Carl M. Way [1] and Albert J. Burky [2]

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A major decision-making problem facing environmental planners and managers is assessing the relative "quality" of a habitat. The rating of biological systems is often used to determine suitable habitats for preservation and development. Unfortunately, decisions on the fate of biological systems are often made using rating systems based on little or no quantitative data. Historically, a major problem has been that biological assessments are much more costly and labor intensive than engineering solutions due to the complexity, variation, and logistics inherent in biological research. Additionally, a good biological assessment tool for managers and planners must be cost effective, timely, relatively simplistic, and generate verifiable results. The Hawai'i Stream Asssessment developed by the Commission on Water Resource Management and the National Park Service was a commendable first attempt to identify Hawaiian streams with important biological and cultural qualities. At the time, however, there was little quantitative basis for many of the biological rating criteria. We have been working to define a suite of quantitative biological criteria for rating Hawaiian streams. We must emphasize that our concept of rating streams based on biological variables is not always correlated to the subjective concept of stream "quality". We have discovered that any rating system must be flexible and consider several biological variables simultaneously. We feel that a combination of several of the following variables would provide an unbiased biological rating of Hawaiian streams: (1) relative density estimates of endemics (gobies, hihiwai, opae); (2) recruitment potential and capacity of a stream for amphidromous species; (3) simple biotic diversity indices; (4) stream productivity ranking using goby feeding dynamics; and (5) "biological condition" of Lentipes concolor (and potentially other gobies). Several of these concepts have been discussed in previous talks. We will present our findings on the use of biodiversity indices, goby feeding dynamics, and the biological condition of L. concolor as a means to rate streams in terms of overall productivity and biodiversity. We are hopeful that future research will lead to a refinement of the assessment techniques which are crucial for the preservation of the unique Hawaiian stream ecosystems.

**Open Discussion** **Tuesday, 2 November 1993**

**1430-1550**

**Panel Discussion:** How can a partnership be formed between scientists, water managers, and policy makers to manage and protect Hawaiian streams?

Panel: ***Members to be announced***

**Open Discussion** **Tuesday, 2 November 1993**

**1600-1730**

**Panel Discussion**: The future of Hawaiian streams: Integrating values

Panel: **Members to be announced**

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